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LEVEL II

FINAL TECHNICAL REPORT.

NONLINEAR PROCESSES IN PLASMAS.

Sponsored by: Air Force Office of Scientific Research

Contract No. F 49620-80-C-0034

Princeton University

Plasma Physics Laboratory

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prepared by Russell M. Kulsrud

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SUMMARY

This final report covers the work carried out under Contract F 49620-80-C-0034 between the Air Force Office of Scientific Research and Princeton University during the period January 1, 1980 to February 28, 1981. (The period January 1, 1981 - February 28, 1981 comprised a no cost extension of the contract that was originally understood to run only till December 31, 1980.)

In accordance with the contract, research was authorized in the following areas:

1) The study of the plasma state of matter, with particular emphasis on its nonlinear collective effects;

2) The application of knowledge gained of the plasma state to the interpretation of various dynamic phenomena in which collective effects play a role such as anomalous transport phenomena, nonlinear wave absorption, and plasma-wave turbulence, both in the laboratory and in space.

In this report, the principle results obtained are described in Part I, papers published or being published are listed in Part II, graduate thesis supported are listed in Part III and research personnel engaged are listed in Part IV.

I. ACTIVITIES AND ACCOMPLISHMENTS

The results obtained under the auspices of this contract are comprised in the list of publications included in part II some of which have already appeared in press and some of which are to soon appear. Some specific interesting results are:

Perkins and Goldman[18] have found that even for frequencies above the maximum ionospheric plasma frequency, sufficiently strong radar signals used to modify the ionosphere are subject to strong instabilities that fluctuate the power of this signal by a factor of order unity. This result enables them to explain the Novozhilov Sovel'yev experiment, (Geomagn, and Aeron 18, 145, 1978). It may put an upper limit on the extent to which the ionosphere may be modified. It appears the power beamed back to earth by a Sattelite Power Station could also be so limited.

Work on tearing modes and reconnection has continued. In an effort to understand major disruptions in Tokamaks the earlier results on helical symmetrics perturbations have been examined for stability against further breakup of the magnetic field.[21] Although it is possible under certain conditions to obtain this further breakup, the conditions are stringent. Since spontaneous reconnection is generally slower than indicated by experiment, efforts have been made to find means to speed it up. It has been found that the introduction of anomalous electron viscosity can lead to substantially faster reconnection.[20] Yet there is the growing feeling that resistive reconnection of smooth equilibria is too slow and that it must be preceded by a strong MHD instability or other nonlinear ideal effects that lead towards a sharp discontinuity in field behaviour.[23]

Considerable progress in the new and exciting field of stochasticity has been made.[14] One interesting result, previously established, was that in magnetic field lines fluttering with sufficient magnitude to produce substantial anomalous electron thermal conductivity, very energetic electrons such as runaways are lost at a substantially slower rate.[10] This should provide a good method to experimentally test the reality of this mechanism for anomalous transport.

A new aproach to the important problem of strange attractors has been made by Jensen and Oberman.[24,25] The evolution of a nonlinear dissipative dynamical system towards a specific nonlinear state is usually approached by reducing the solution to a sequence of discrete maps of the dynamical states on to each other and considerable effort has been directed to studying the large iterates of these maps in their own right. Jensen and Oberman have shown that the statistics of such maps is very amenable to the path integral method and are obtaining results in exact agreement with numerical experiments.

Finally, the stability conditions for the interpretation of two ion beams of equal density or of one ion beam into a plasma of equal density has been determined.[2] During the extension period considerable effort has been devoted to the study of the physics of this problem for unequal densities. Work on this problem is continuing under a subsequent Air Force Office of Scientific Research Grant.

The above are only some examples of the results of interest obtained during the past year. Further examples may be found by inspection of the papers themselves. They represent work done by members of the contract often working with others, students and colleagues not under direct support of the contract. However, the investigations were largely initiated and inspired by these members.

II. PUBLICATIONS

1. E. A. Adler, R. M. Kulsrud, and R. B. White, "Magnetic Driving Energy of the Collisional Tearing Modes," Physics of Fluids, 23, 1375, 1980.

2. E. A. Foote and R. M. Kulsrud, "The Stability of Colliding Ion Beams," Physics of Fluids, (to appear in August 1981 issue).

3. H. P. Freund, C. S. Liu, and R. M. Kulsrud, "Relativistic Effects in Strong Langmuir Turbulence," Journal of Plasma Physics, (in press).

4. P. K. Kaw and P. N. Guzdar, "The Universal Mode Revisited," comments in Plasma Physics, 5, 189, 1980.

5. P. K. Kaw, E. J. Valeo, and A. Sen, "Nonlinear Coupled Stationary Waves in an Unmagnetized Plasma," Kiev Conference on Nonlinear and Turbulent Processes in a Plasma, Kiev Sept. 1979.

6. P. K. Kaw and R. N. Sudan, "Mode Conversion Induced Tearing Effects in a Plasma Neutral Sheet," Journal for Geophysical Research (in press).

7. L. Chen, M. S. Chance, ... P. K. Kaw ..., "Theory of Drift Trapped-Particle and Alfven Instabilities and Anomalous Plasma Transport," 8th Int'l. Conference on Plasma Physics and Controlled Nuclear Fusion Research (Brussels 1980).

8. D. A. Monticello, W. Park, ... P. K. Kaw, P. H. Rutherford, and E. J. Valeo, "Linear and Nonlinear Studies of High β Tokamaks," ibid.

9. J. K. Krommes, "Renormalized Compton Scattering and Nonlinear Damping of Collisionless Drift Waves," Physics of Fluids 23, 736, 1980.

10. H. E. Mynick and J. A. Krommes, "Particle Stochasticity due to Magnetic Perturbations of Axisymmetric Geometries," Physics of Fluids 23, 1229, 1980.

11. J. A. Krommes and P. Similon, "Dielectric Response in a Guiding Center Plasma," Physics of Fluids 23, 8, 1980.

12. J. A. Krommes, "Incoherent Noise and Self Consistency in Stochastically Unstable Plasma," Princeton Plasma Physics Matt Report PPL-1603.

13. J. A. Krommes, "Comments on 'Adiabatic Modifications to Plasma Turbulence Theory,'" Phys. Fluids (in press).

14. J. A. Krommes, "Self Consistent Kinetic Theory of Stochasticity," Instrinsic Stochasticity in Plasma edited by G. Laval and D. Gresillon (Editions de Physique, Orsay, 1979).

15. J. A. Krommes, "Renormalization in Plasma Physics," article for Handbook of Plasma Physics, North Holland, editors R. N. Sudan and A. Galeev to appear.

16. C. R. Oberman, "Theory of Fluctuations," ibid.

17. R. M. Kulsrud, "MHD Description of Plasma," ibid.

18. M. V. Goldman and F. W. Perkins "Self Focussing of Radio Waves in an Underdense Plasma," Journal of Geophysical Research 86, 600, 1981.

19. F. W. Perkins and Y. C. Sun, "Double Layers without Current," Phys. Rev. Letters 46, 115, 1981.

20. P. Kaw, E. J. Valeo, and P. H. Rutherford, "Tearing Modes in a Plasma with Magnetic Braiding," Phys. Rev. Lett. 43, 1398, 1979.

21. E. J. Valeo, P. K. Kaw, D. A. Monticello, and R. B. White, "Stability of Helically Symmetric Equilibria to Ideal MHD Perturbations," (submitted to Phys. Fluids).

22. D. H. E. Dubin and J. A. Krommes, "Stochasticity, Superadiabaticity and the Theory of Adiabatic Invariants and Guiding Center Motion," Proceedings of the Workshop on Long Time Predictions in Nonlinear Dynamic Systems (Lakeway, Texas March 1981).

23. E. A. Adler and R. M. Kulsrud, "A Model for Magnetic Reconnection," (submitted to Phys. Fluids.)

24. R. V. Jensen and C. R. Oberman, "Calculation of the Statistical Properties of Strange Attractors," Phys. Rev. Lett. (in press).

25. R. V. Jensen and C. R. Oberman, "Calculation of the Statistical Properties of Turbulent Dynamical Systems" (submitted to Physica D).

III. Ph.D. THESES SUPPORTED

No thesis related to this contract was completed during this period. However, four Ph.D. Theses students were supervised by members of this contract during the entire period and all are expected to finish during 1981. None of them were directly supported by the contract.

(1)   Rick Jensen's thesis topic is "Path Integral Methods in Nonlinear Statistical Dynamics." He is supervised by C. R. Oberman.

(2)   Phillipe Similion's thesis topic is "A Statistical Theory of Drift Waves." He is supervised by J. A. Krommes.

(3)   Michael Kotschenreuther's thesis topic is "The Effects of Microturbulence on Tearing Modes." He is jointly supervised by J. A. Krommes and C. R. Oberman.

(4)   Goran Schultze's thesis topic is "General Theory of Tearing Modes." He is supervised by P. K. Kaw and R. M. Kulsrud.

IV. PERSONNEL SUPPORTED

The personnel supported during the 14 month period of this contract were E. A. Foote, P. K. Kaw, J. A. Krommes, R. M. Kulsrud, C. R. Oberman, F. W. Perkins, and E. J. Valeo. Foote was supported only during February 1981. Her married name now is Chrien.

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